Roaming Support

Feature Summary

Summary Data

Table 1: Summary Data

Applicable Product(s) or Functional Area	5G-UPF
Applicable Platform(s)	VPC-SI SMI
Feature Default Setting	Enabled – Always-on
Related Changes in this Release	Not Applicable
Related Documentation	Not Applicable

Revision History

Table 2: Revision History

Revision Details	Release
UPF supports inter-PLMN roaming mobility and secondary PDR for 5G sessions.	2023.03.0

Revision Details	Release
UPF supports the following roaming functionalities: • Source Interface Type IE indicates the 3GPP Interface Type • Subscriber Params IE indicates the roaming status	2023.02.0
First introduced.	2021.02.0

Feature Description

The mobile network operators form roaming partnerships to provide seamless services to their subscribers in geographies beyond their network reach. Operator network boundaries are designated by public land mobile networks (PLMN). The home network for a subscriber is called an HPLMN and the visited network, which renders the mobile service is termed as the VPLMN.

The VPLMN provides access network services and packet routing to the packet core, whereas the HPLMN provides data network access to the subscriber. This feature enables the UPF to support the flavor of routing that is termed as the Home Routed (HR) roaming.

Visited UPF (vUPF) supports the following functionalities:

- Handle the dummy PDRs with associated FAR action as buffer
- Buffer the incoming packets before rule matching
- Handle the QoS and FAR updates from the SMF for debuffering of packets
- Send the buffered packets after matching with the PDR
- Send vUPF traffic over Fast Path
- Send N9 interface GTP-U tunnel
- UPF LI support is extended for roaming
- MonSub CLI command and PCAP file support

vUPF and Home UPF (hUPF) support the following functionalities:

- QoS flow Based Charging (QBC) on the UPF
- Source Interface Type IE in PDR indicates the 3GPP Interface Type in UPF
- Selection of the GTP-U service by receiving 3GPP Interface Type received in PDI IE of create PDR.
- Subscriber Params IE indicates the roaming status in UPF

Relationships

The roaming status functionality relates to the UPF Ingress Interfaces feature that indicates the following types of roaming:

- Homer
- Roamer
- Visited LBO
- Visited HR

The UPF supports different GTP-U ingress interfaces. It allows a separate network for the N3 interface and N9, S5u, and S8u interfaces.

The GTP-U ingress interfaces to handle roaming and outbound calls include:

- N3—N3 is the interface between gNodeB and UPF. To handle 5G home calls, the N3 interface must be a private IP address.
- N9—The N9 interface connects two UPFs. It is the interface between intermediate I-UPF and UPF session anchor connecting different PLMN. To handle 5G outbound roaming calls, the N9 interface must be a public IP address.
- S5u—S5u is similar to the N9 interface that connects two UPFs. The interface connects the intermediate I-UPF and UPF session anchor. To handle 4G inbound calls, the S5u is set to a public IP since the SGW-U is public for enabling the S-GW.
- S8u—S8u is an inter-PLMN variant of the S5u interface. To handle 4G outbound roaming calls, the S8u interface must be a public IP address.

For more information, refer to the *UPF Ingress Interfaces* chapter.

Architecture

This section describes the architecture for the home routing roaming support feature.

Bufffering and Debuffering on the vUPF

The buffering and debuffering procedure on the vUPF for the UPF HR roaming, are as follows:

1. Two dummy PDRs (UL or DL) is created initially at vUPF by vSMF with default value as QFI and the buffering as an FAR action.
2. The packets coming from the N3 and N9 interfaces get buffered based on the FAR action before doing a packet classification and application of policy.
3. If buffered packet count exceeds the configured limits then the subsequent packets are dropped.
4. The buffered packets are sent for classification and policy application after the update FAR is received with action as forward and updated TEID in modify request from vSMF.
5. The vSMF initiates the removal of default QER and URR while sending the update FAR with action forward and sends a new PDR with the required QER and URR.
6. The packets are sent on the required interface that is based on the QFI defined in the new QER.
7. If there is no matching PDR with TEID and QFI installed then the debuffered packets is dropped.

Charging — Predef and Dynamic Rules on the hUPF

The charging predef and dynamic rules on the hUPF, are as follows:

1. The SMF associates FBC URRs + QBC URRs + Session URRs with dynamic PDRs.
2. The SMF associates QBC URRs + Session URRs with predef PDRs.
3. The UPF associates the URRs created by installed global PDRs to the received predef PDRs QBC URRs + Sess URRs.
4. The QBC URRs have no Linked URRs.
5. The QBC URRs include no FBC URRs or Session URRs usage reporting.
6. The UPF links the Session URRs to FBC URRs as Linked URRs.
7. The Session URRs include FBC URRs and QBC URRs usage reporting.
8. The UPF relies on the SMF for the update or removal of each of the QBC and Sess URRs.

Charging — Static Rules on the hUPF

The charging static rules on the hUPF, are as follows:

1. The SMF associates FBC URRs + QBC URRs + Session URRs with RB PDRs.
2. The UPF associates the URRs created by installed global PDRs to the received RB PDRs QBC URRs + Sess URRs.
3. The UPF does not link QBC URRs with any URRs.
4. The UPF links the static FBC URRs with the Session URRs.
5. The UPF links the Session URRs to the FBC URRs as linked URRs for usage reporting.
6. The UPF relies on the SMF for the update or removal of each of the QBC and the SMF URRs.

Inter-PLMN Mobility Support

The Inter-Public Land Mobile Network (Inter-PLMN) mobility feature allows the PLMN to change from home-PLMN to visited-PLMN when a User Equipment (UE) moves from its home network to a visited network and vice-versa. This feature provides support for various types of Inter-PLMN mobility cases.

For information on the call flows related to inter-PLMN handover, see the *How it Works* section.

H-UPF Data Path specifications:

- Secondary PDR optimization for Homer calls
- Inter-PLMN and Intra-PLMN handover support with optimization
- Supports GTPU services for Homer calls
- KPI support for Secondary PDR info in PDR
- Handover statistics

UPF supports the following scenarios for various Inter-PLMN mobility:

- 5G homer to 5G roamer
- 5G homer to 4G roamer
- 4G homer to 5G roamer
- 4G homer to 4G roamer
- 5G roamer to 5G homer
- 5G roamer to 4G homer
- 4G roamer to 5G homer
- 4G roamer to 4G homer

UPF supports the following scenarios for various Intra-PLMN mobility:

- 5G homer to 4G homer
- 4G homer to 5G homer
- 5G roamer to 4G roamer
- 4G roamer to 5G roamer
- EUTRAN to WiFi and vice-versa handover

How it Works

This section describes the call flows related to the roaming feature in UPF.

PDU Session Establishment Procedure

This call flow describes the PDU Session Establishment procedure for the UPF.

Figure 1: PDU Session Establishment Call Flow

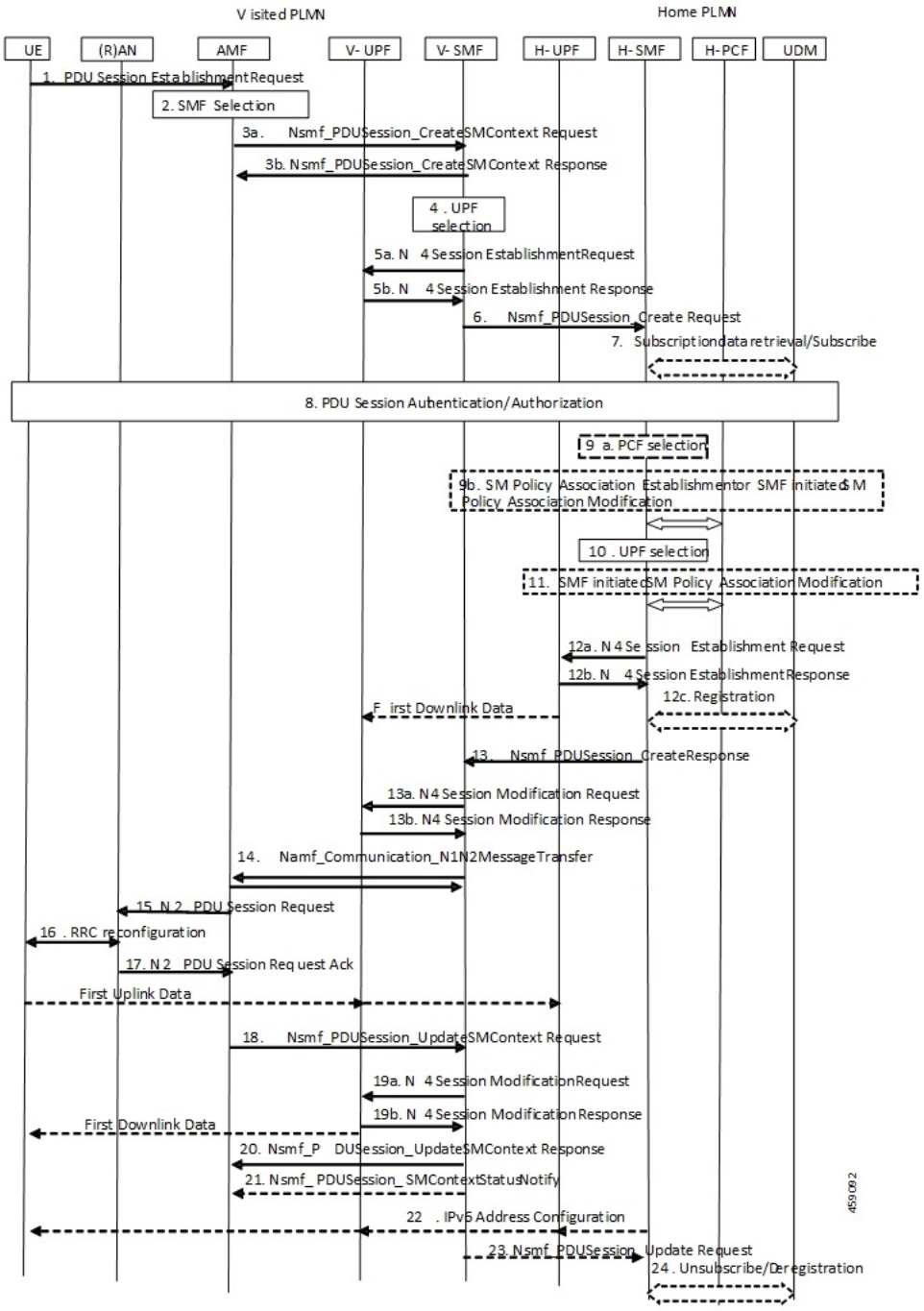

Table 3: PDU Session Establishment Call Flow Description

Step	Description
1	The UE initiates a PDU Session Establishment Request to the AMF.

Step	Description
2	The AMF selects an SMF.
3a	The AMF invokes the Nsmf_PDUSession_CreateSMContext Request and sends it to the vSMF.
3b	The vSMF sends a Nsmf_PDUSession_CreateSMContext Response to the AMF.
4	The vSMF selects a UPF in VPLMN.
5a	The vSMF sends an N4 Session Establishment Request with dummy PDRs, FARs, QERs, or URRs to the vUPF. In this request, the vSMF informs the vUPF to allocate the CN Tunnel information for the N3 and N9 interfaces. The vSMF sends Source Interface Type IE in Access PDR as N3 3GPP Access (11), and in Core PDR as N9 (21) for roaming.
5b	The vUPF creates the N3 and N9 CN tunnel information and acknowledges by sending this information in an N4 Session Establishment Response.
6	The vSMF sends an Nsmf_PDUSession_Create Request to the hSMF.
7	The hSMF registers with the UDM for a given PDU session.
8	The SMF performs a secondary authorization or authentication during the establishment of the PDU session by a DN-AAA server.
9a	The hSMF selects the PCF.
9b	The SMF performs an SM Policy Association Establishment procedure to establish an SM Policy Association with the PCF and get the default PCC rules for the PDU session.
10	The hSMF selects the UPF.
11	The hSMF initiates an SM Policy Association Modification procedure.
12a	The hSMF initiates an N4 Session Establishment procedure with the selected UPF. The N9 CN tunnel information from the vUPF is transferred to hUPF in FAR. The hSMF sends Source Interface Type in Access PDR as N9(21) or N3 3GPP ACCESS (11) or S5u interface depending on the RAT and roaming status where it registers the call.
12b	The UPF acknowledges by sending an N4 Session Establishment Response. The hUPF provides the N9 CN tunnel information to the vUPF.
12c	The downlink path is established between the hUPF and vUPF and data packets are sent to the vUPF where it gets buffered.
13	The hSMF sends an Nsmf_PDUSession_Create Response message to the vSMF.
14	The vSMF sends an Namf_Communication_N1N2MessageTransfer message to the AMF.
15	The AMF sends the NAS message containing PDU Session ID and PDU Session Establishment Accept targeted to the UE and the N2 SM information received from the SMF within the N2 PDU Session Request to the RAN.
16	The RAN issues AN specific signalling exchange with the UE that is related with the information received from SMF.

Step	Description
17	The RAN sends an N2 PDU Session Response message to the AMF.
18	The AMF sends the Nsmf_PDUSession_UpdateSMContext Request message to the vSMF. The AMF forwards the N2 SM information received from RAN to the vSMF.
19a	The vSMF initiates an N4 Session Modification procedure with the vUPF. The vSMF provides packet detection, enforcement, and reporting rules to be installed on the vUPF for this PDU session, including AN Tunnel Information, H-CN Tunnel Information and V-CN Tunnel Information.
19b	The vUPF provides an N4 Session Modification Response to the vSMF. After this step, the vUPF delivers any down-link packets to the UE that might have been buffered for this PDU Session.
20	The vSMF sends an Nsmf_PDUSession_UpdateSMContext Response message to the AMF.
21	The vSMF sends an Nsmf_PDUSession_SMContextStatusNotify message to the AMF.
22	If it's a PDU session of type IPv6 or IPv4v6, the hSMF generates an IPv6 Router Advertisement and sends it to the UE through the N4 interface, hUPF, and vUPF.
23	If the vSMF received in step 18 is an indication that the RAN has rejected some QFIs the vSMF notifies the hSMF through an Nsmf_PDUSession_Update Request. The hSMF is responsible for updating the QoS rules and QoS Flow level QoS parameters for the QoS Flow(s) associated with the QoS rule(s) in the UE accordingly.
24	If the PDU Session establishment failed after step 4, the hSMF performs the following steps: • If the SMF is no more handling a PDU Session of the UE for this (DNN, S-NSSAI), the hSMF unsubscribes to the modifications of Session Management Subscription data for the corresponding (SUPI, DNN, S-NSSAI), by using Nudm_SDM_Unsubscribe. • The hSMF deregisters for the given PDU Session by using Nudm_UECM_Deregistration (SUPI, DNN, PDU Session ID).

PDU Session Modification Procedure

This call flow describes the PDU Session Modification procedure for the UPF.

Figure 2: PDU Session Modification Call Flow

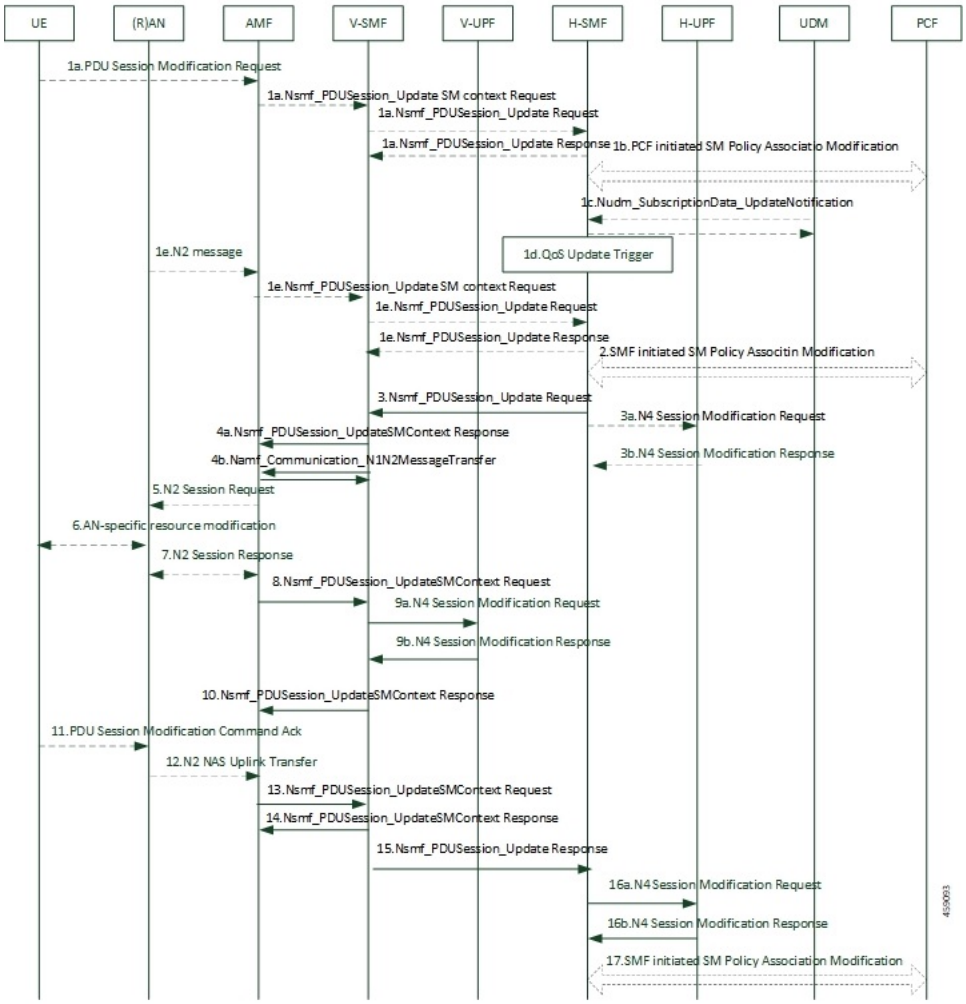

Table 4: PDU Session Modification Call Flow Description

Step	Description
1a	• The UE initiates the PDU Session Modification procedure by the transmission of an NAS message to the AMF. • The AMF initiates the Nsmf_PDUSession_UpdateSMContext message. • The vSMF sends an Nsmf_PDUSession_Update Request message to the hSMF. • The hSMF acknowledges and sends an Nsmf_PDUSession_Update Response message to the vSMF.
1b	The PCF performs a PCF initiated SM Policy Association Modification procedure to notify SMF about the modification of policies.

Step	Description
1c	The UDM updates the subscription data of hSMF by Nudm_SDM_Notification (SUPI, Session Management Subscription Data). The hSMF updates the Session Management Subscription Data and acknowledges the UDM by returning an Ack with (SUPI).
1d	The SMF might modify the PDU session. This procedure can also be triggered based on locally configured policy or triggered from the RAN.
1e	RAN indicates to the SMF when the AN resources onto which a QoS Flow is mapped are released irrespective of whether notification control is configured. RAN sends the N2 message to the AMF. The AMF invokes Nsmf_PDUSession_UpdateSMContext procedure. The vSMF sends an Nsmf_PDUSession_Update Request message to the hSMF. The hSMF acknowledges and sends an Nsmf_PDUSession_Update Response message to the vSMF.
2	The SMF reports some subscribed event to the PCF by performing an SMF initiated SM Policy Association Modification procedure.
3	The hSMF invokes the Nsmf_PDUSession_Update Request service operation to the vSMF.
3a	The hSMF initiates an N4 Session Modification procedure with the selected hUPF.
3b	The hUPF acknowledges and sends an N4 Session Modification Response message to the hSMF.
4a	The vSMF sends an Nsmf_PDUSession_UpdateSMContext Response message to the AMF.
4b	The vSMF sends an Nsmf_PDUSession_SMContextStatusNotify message to the AMF.
5	The AMF sends the NAS message containing PDU Session ID and PDU Session Establishment Accept targeted to the UE and the N2 SM information received from the SMF within the N2 PDU Session Request to the RAN.
6	The RAN issues AN specific signalling exchange with the UE that is related with the information received from SMF.
7	The AMF sends the Nsmf_PDUSession_UpdateSMContext Request message to the vSMF. The AMF forwards the N2 SM information received from RAN to the vSMF.
8	The AMF sends the Nsmf_PDUSession_UpdateSMContext Request message to the vSMF. The AMF forwards the N2 SM information received from RAN to the vSMF.
9a	The vSMF initiates an N4 Session Modification procedure with the vUPF. The vSMF provides packet detection, enforcement, and reporting rules to be installed on the vUPF for this PDU session, including AN Tunnel Information, H-CN Tunnel Information and V-CN Tunnel Information.
9b	The vUPF provides an N4 Session Modification Response to the vSMF. After this step, the vUPF delivers any down-link packets to the UE that might have been buffered for this PDU Session.
10	The vSMF sends an Nsmf_PDUSession_UpdateSMContext Response message to the AMF.
11	The UE sends a PDU Session Modification Command Ack message to the RAN.
12	The RAN initiates an N2 NAS Uplink Transfer with the AMF.

Step	Description
13	The vSMF sends an Nsmf_PDUSession_UpdateSMContext Response message to the AMF.
14	The vSMF sends an Nsmf_PDUSession_SMContextStatusNotify message to the AMF.
15	The vSMF responds to the hSMF with an Nsmf_PDUSession_Update response carrying the information like PCO provided by the UE in the SM PDU Session Modification Command Ack message from the UE to the vSMF. The hSMF modifies the PDU session context.
16a	The vSMF initiates an N4 Session Modification procedure with the vUPF. The vSMF provides packet detection, enforcement, and reporting rules to be installed on the vUPF for this PDU session, including AN Tunnel Information, H-CN Tunnel Information and V-CN Tunnel Information.
16b	The vUPF provides an N4 Session Modification Response to the vSMF. After this step, the vUPF delivers any down-link packets to the UE that might have been buffered for this PDU Session.
17	The hSMF initiates an SM Policy Association Modification procedure.

PDU Session Release Procedure

This call flow describes the PDU Session Release procedure for the UPF.

Figure 3: PDU Session Release Call Flow

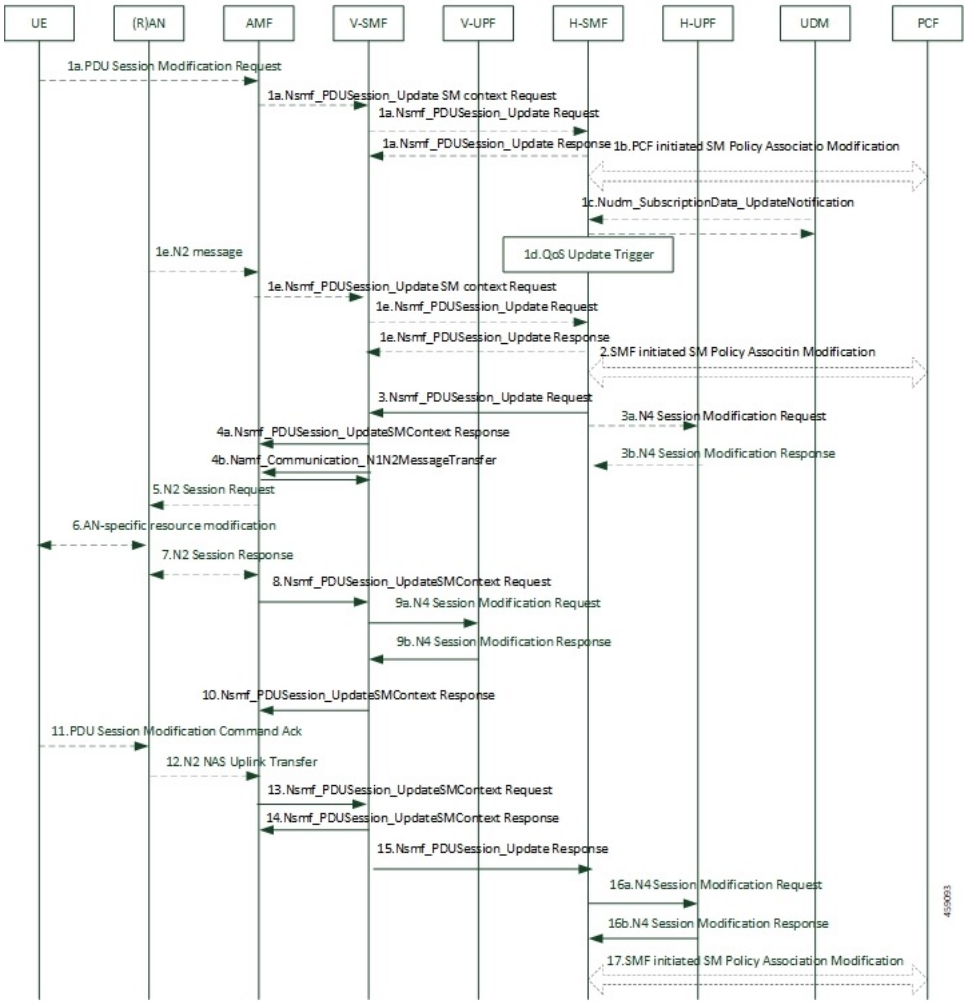

Table 5: PDU Session Release Call Flow Description

Step	Description
1a	• The UE initiates the UE Requested PDU Session Release procedure by the transmission of an NAS message to the AMF. • The AMF invokes the Nsmf_PDUSession_UpdateSMContext service operation and provides the N1 SM container to the SMF together with User Location Information (ULI) received from the RAN. • The vSMF initiates N4 Session Modification to instruct the vUPF to stop forwarding uplink traffic. • The vSMF invokes the Nsmf_PDUSession_Update Request service operation to request the hSMF to release the PDU Session. The hSMF responds to the request immediately.

Step	Description
1b	• The AMF invokes the Nsmf_PDUSession_ReleaseSMContext service operation to request the release of the PDU Session. • The vSMF initiates N4 Session Modification to instruct the vUPF to stop forwarding uplink traffic. • The vSMF initiates the release of the PDU Session at the hSMF by invoking the Nsmf_PDUSession_Release request.
1c	• The PCF invokes an SM Policy Association Termination procedure to request the release of the PDU Session. • The hSMF initiates N4 Session Modification to instruct the hUPF to stop forwarding downlink traffic.
1d	• RAN indicates to the vSMF that the PDU Session-related resource is released when all the QoS Flow(s) of the PDU Session are released. • The vSMF initiates N4 Session Modification to instruct the vUPF to stop forwarding uplink traffic. • The vSMF initiates the Nsmf_PDUSession_Update Request toward the hSMF and the hSMF acknowledges with a response.
1e	The SMF decides to release a PDU session. The hSMF initiates N4 Session Modification to instruct the hUPF to stop forwarding downlink traffic.
1f	The AMF invokes the Nsmf_PDUSession_UpdateSMContext service operation with a release indication to request the release of the PDU session. The vSMF initiates N4 Session Modification to instruct the vUPF to stop forwarding uplink traffic. The vSMF invokes the Nsmf_PDUSession_Update Request toward the hSMF.
2a	The hSMF sends an N4 Session Release Request (N4 Session ID) message to the hUPFs of the PDU session. The hUPFs drop any remaining packets of the PDU session and release all tunnel resource and contexts associated with the N4 Session.
2b	The hUPF(s) acknowledges the N4 Session Release Request by the transmission of an N4 Session Release Response message to the hSMF.
3a	The SMF responds to the AMF with the Nsmf_PDUSession_UpdateSMContext response.
4a	The vSMF sends an N4 Session Release request to the vUPF.
4b	The vUPF acknowledges and sends an N4 Session Release response to the hSMF.
5a	The vSMF sends an Nsmf_PDUSession_ReleaseSMContext Response message to the AMF.
5b	The vSMF sends an Nsmf_PDUSession_UpdateSMContext Response message to the AMF.
5c	The N1N2 Message Transfer procedure occurs between the AMF and vSMF.

Step	Description
6	The hSMF includes the N2 SM Resource Release request in the message sent to the AMF, then the AMF transmits the NAS message to the UE.
7	When the RAN receives an N2 SM request to release the AN resources associated with the PDU session, it issues AN specific signalling exchanges with the UE to release the corresponding AN resources.
8	If the RAN receives an N2 SM request to release the AN resources, it acknowledges the N2 SM Resource Release Request by sending an N2 SM Resource Release Ack message to the AMF.
9	The AMF sends an Nsmf_PDUSession_UpdateSMContext Response message to the vSMF.
10	The vSMF responds to the AMF with an Nsmf_PDUSession_UpdateSMContext response.
11	The UE acknowledges the PDU Session Release Command by sending a NAS message over the RAN.
12	The AMF invokes the Nsmf_PDUSession_UpdateSMContext to the vSMF.
13	The SMF responds to the AMF with an Nsmf_PDUSession_UpdateSMContext response.
14	The vSMF responds to the hSMF with an Nsmf_PDUSession_Update Request invoked at step 3a and confirms the PDU session release.
15	The vSMF initiates an N4 Session Modification procedure with the vUPF. The vSMF provides packet detection, enforcement, and reporting rules to be installed on the vUPF for this PDU session, including AN Tunnel Information, H-CN Tunnel Information and V-CN Tunnel Information.
15a	The hSMF releases the SM policy control association with the PCF by invoking the SM Policy Association Termination procedure.
15b - 15c	In case the PDU Session Release is HPLMN-initiated, the hSMF releases the corresponding User Plane resources.
15d	The hSMF invokes the Nudm_UECM_Deregistration service operation.
16a	The hSMF requests the vSMF to release all contexts associated with the PDU session by invoking the Nsmf_PDUSession_StatusNotify (Release) operation.
16b	The vSMF requests the AMF to release all contexts associated with the PDU Session by invoking the Nsmf_PDUSession_SMContexStatusNotify (Release). The AMF releases the association between the vSMF ID and the PDU Session ID.

5G to 4G Handover

This call flow describes the 5G to 4G handover.

Figure 4: 5G to 4G Handover Call Flow

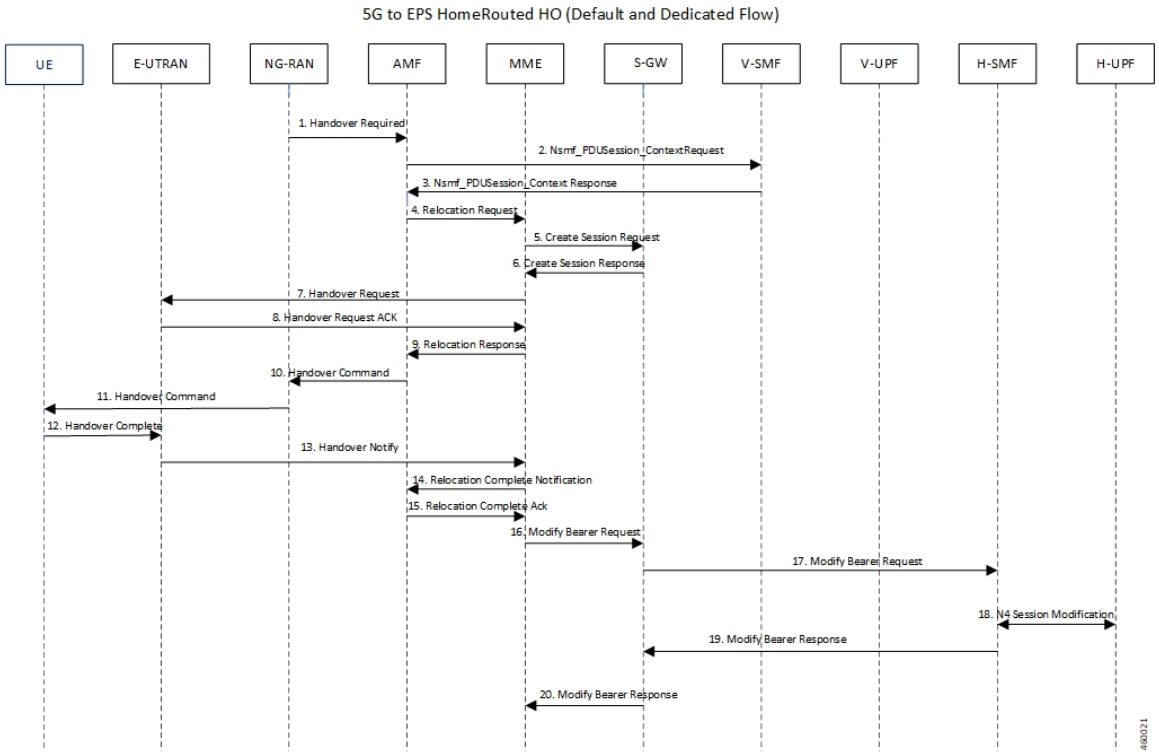

Table 6: 5G to 4G Handover Call Flow Description

Step	Description
1	After the 5G session is established, the NG-RAN initiates the handover process by sending the Handover Required message to the AMF.
2	The AMF invokes the Nsmf_PDUSession_Context Request and sends it to the vSMF.
3	The vSMF sends a Nsmf_PDUSession_Context Response to the AMF.
4	The AMF sends a Relocation Request to the MME.
5	The MME sends Create Session Request to the S-GW.
6	The S-GW sends a Create Session Response message back to the MME.
7	The MME sends a Handover Request message to E-UTRAN.
8	The E-UTRAN acknowledges and sends a Handover Request ACK message back to the MME.
9	The MME sends the Relocation Response message to the AMF.
10	The AMF sends a Handover Command message to the NG-RAN.

Step	Description
11	The NG-RAN commands the UE to handover to the target access network by sending the Handover Command.
12	The UE responds to the E-UTRAN with a Handover Complete message, and the uplink data path is established.
13	The E-UTRAN notifies the MME that the UE is handed over to the NG-RAN.
14	The MME sends a Relocation Complete Notification message to the AMF.
15	The AMF acknowledges and sends a Relocation Complete Ack message to the MME.
16	The MME sends a Modify Bearer Request message to the S-GW.
17	The S-GW forwards the Modify Bearer Request message to the hSMF.
18	The hSMF initiates an N4 Session Modification procedure with the hUPF.
19	The hSMF responds to the S-GW with a Modify Bearer Response message, and the downlink data path is established.
20	The S-GW sends the Modify Bearer Response message to the MME.

4G to 5G Handover

This call flow describes the 4G to 5G handover.

Figure 5: 4G to 5G Handover Call Flow

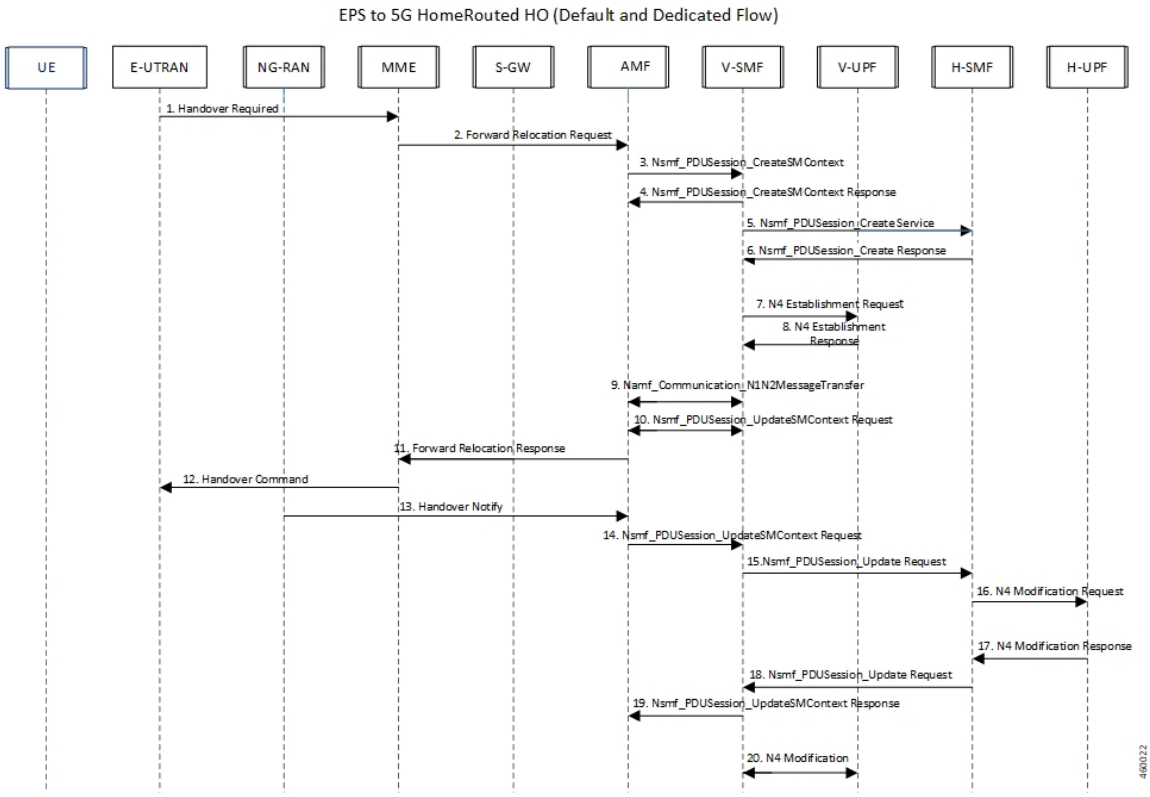

Table 7: 4G to 5G Handover Call Flow Description

Steps	Description
1	After the 4G session is established, the E-UTRAN initiates the handover process by sending the Handover Required message to the MME.
2	The MME sends a Forward Relocation Request to the AMF.
3	The AMF invokes the Nsmf_PDUSession_CreateSMContext Request and sends it to the vSMF.
4	The vSMF sends a Nsmf_PDUSession_CreateSMContext Response to the AMF.
5	The vSMF sends a Nsmf_PDUSession_Create Service message to create a new PDU Session in the hSMF.
6	The hSMF responds with a Nsmf_PDUSession_Create Response message.
7	The vSMF sends an N4 Establishment Request to the vUPF.
8	The vUPF acknowledges by sending an N4 Establishment Response.
9	The vSMF sends an Namf_Communication_N1N2MessageTransfer message to the AMF.
10	The AMF sends the Nsmf_PDUSession_UpdateSMContext Request message to the vSMF.

Steps	Description
11	The AMF sends a Forward Relocation Response message to the MME.
12	The MME sends the Handover Command to the E-UTRAN.
13	The NG-RAN notifies the AMF that the UE is handed over to the NG-RAN.
14	The AMF sends the Nsmf_PDUSession_UpdateSMContext Request message to the vSMF.
15	The vSMF initiates the Nsmf_PDUSession_Update Request toward the hSMF.
16	The hSMF sends an N4 Modification Request with PDRs, FARs, QERs, or URRs to the hUPF.
17	The hUPF responds with an N4 Modification Response message.
18	The hSMF invokes the Nsmf_PDUSession_Update Request service operation to the vSMF.
19	The vSMF sends an Nsmf_PDUSession_UpdateSMContext Response message to the AMF.
20	The vSMF initiates an N4 Modification procedure with the vUPF.

Note To support the roaming status functionality, the Roaming Status IE is sent in Subscriber Params during PDU Session Establishment or during handover.

Inter-PLMN 5G HO from Homer to Roamer

This call flow describes the inter-PLMN 5G handover (HO) procedure with v-SMF insertion.

The UE moves from a homer in H-PLMN to a roamer in V-PLMN. When V-SMF is newly inserted, SMF transitions to H-SMF.

Figure 6: Inter-PLMN 5G HO from Homer to Roamer Call Flow

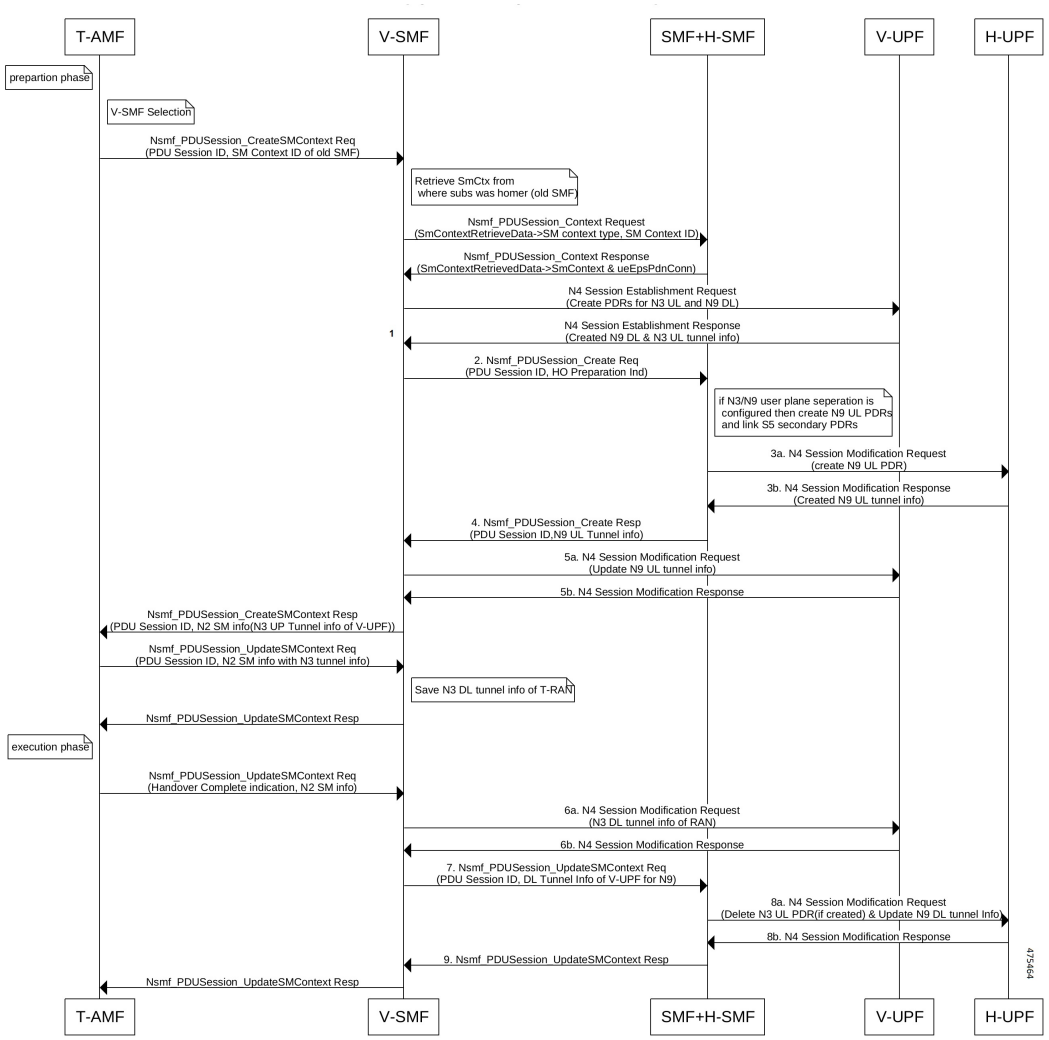

Table 8: Inter-PLMN 5G HO from Homer to Roamer Call Flow Description

Steps	Description
1	UE moves from H-PLMN (5G Homer) to V-PLMN (5G Roamer).
2	V-SMF sends Nsmf_PDUSession_Create Request with HO Preparation Ind info to the H-SMF.
3a	H-SMF sends the following Create PDRs in an N4 Session Modification Request to the H-UPF: • Primary Create PDR with Source Interface Type as N9, Local FTEID having the same FTEID as assigned in S5U Create PDR. • Secondary Create PDR with Source Interface Type as S5-U, Local FTEID having the same FTEID as assigned in S5U Create PDR.
3b	H-UPF sends N4 Session Modification Response with created N9 UL Tunnel info to the H-SMF.

Steps	Description
4	H-SMF sends Nsmf_PDUSession_Create Response with N9 UL Tunnel info to the V-SMF.
5a	V-SMF sends N4 Session Modification Request with N9 UL Tunnel info to the V-UPF.
5b	V-UPF sends N4 Session Modification Response back to the V-SMF.
6a	V-SMF sends N4 Session Modification Request with N3 DL Tunnel Info of RAN to the V-UPF.
6b	V-UPF sends N4 Session Modification Response back to the V-SMF.
7	V-SMF sends Nsmf_PDUSession_UpdateSMContext Request with DL Tunnel info of V-UPF for N9 to the H-SMF.
8a	H-SMF deletes N3 UL PDR (if created), updates N9 DL tunnel Info in an N4 Session Modification Request and sends to the H-UPF. H-SMF sends Create N9 DL FAR, Remove old N3 PDR, Remove old S5 PDR, Remove FAR, Create Core QER, and Update Core PDR in Sx-Modify.
8b	H-UPF sends N4 Session Modification Response back to the H-SMF.
9	H-SMF sends Nsmf_PDUSession_UpdateSMContext Response back to the V-SMF.

Inter-PLMN HO from 5G Roamer to 4G Homer

This call flow describes the inter-PLMN HO from 5G roamer to 4G homer.

Figure 7: Inter-PLMN HO from 5G Roamer to 4G Homer Call Flow

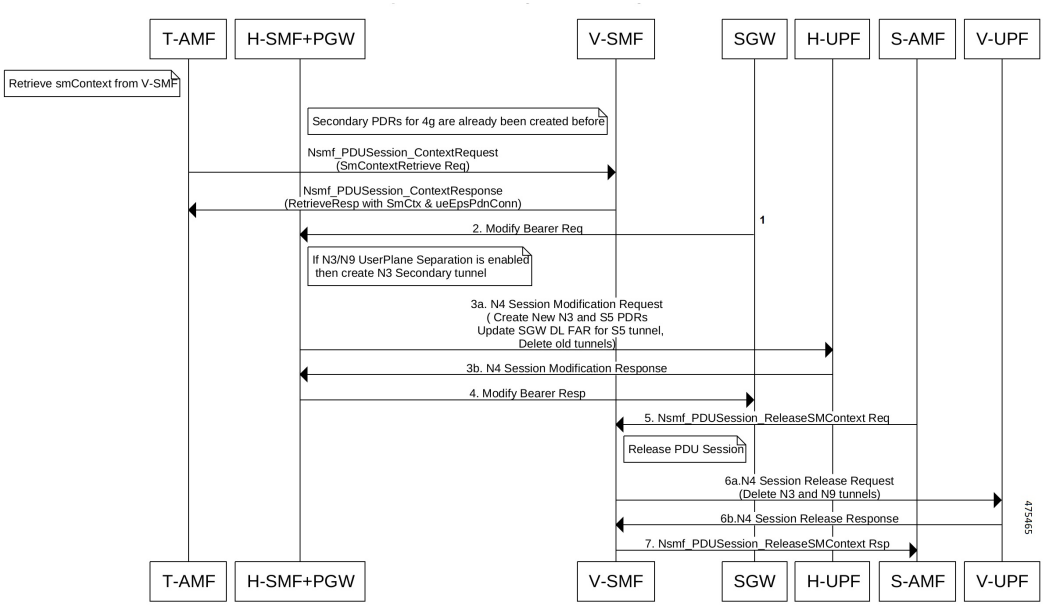

Table 9: Inter-PLMN HO from 5G Roamer to 4G Homer Call Flow Description

Steps	Description
1	UE moves from H-PLMN (5G Roamer) to V-PLMN (4G Homer).

Steps	Description
2	S-GW sends Modify Bearer Request to the H-SMF. Here, if N3/N9 UserPlane Separation is enabled then create N3 secondary tunnel.
3a	H-SMF sends N4 Session Modification Request to H-UPF with the following IEs: Create S5 PDR (old S5-U FTEID), Create N3 PDR (CH bit set for New FTEID), Create S5 DL FAR, Remove old N9 PDR, Remove old S5 PDR, Remove FAR, and Update Core QER.
3b	H-UPF sends N4 Session Modification Response back to the H-SMF.
4	H-SMF sends Modify Bearer Response back to the S-GW.
5	S-AMF sends Nsmf_PDUSession_ReleaseSMContext Request with Release PDU Session to the V-SMF.
6a	V-SMF sends N4 Session Release Request with Delete N3,N9 tunnels to the V-UPF.
6b	V-UPF sends N4 Session Release Response back to the V-SMF.
7	V-SMF sends Nsmf_PDUSession_ReleaseSMContext Response back to the S-AMF.

Standards Compliance

The HR roaming support feature complies with the following standards:

- 3GPP TS 23.502 "Procedures for the 5G System"
- 3GPP TS 29.061 "Interworking between the Public Land Mobile Network (PLMN) supporting packet based services and Packet Data Networks (PDN)"
- 3GPP TS 29.244 16.5.0 "Interface between the Control Plane and the User Plane nodes"

Limitations

The HR roaming support feature has the following limitations:

- Router Advertisement (RA) or Router Solicitation (RS) packets are charged and counted in default QFI PDR on the vUPF.
- No support for QER enforcement policing on the vUPF.
- No support for LI on the vUPF.
- UPF supports two GTPU endpoints at the ingress interface.
- Secondary PDR Optimization support will not be enabled in-between, for an existing call.
- After the upgrade, if the source interface type is not available in Create PDR.Then for existing calls, service selection will not happen based on interface type.
- N9, S5U, and S8U interface types are supported only on the same public IP and not on different IPs.
- Inter-PLMN handover works only with Secondary PDR optimization.

- If any Access-side PDR handling fails, then UPF reports only the failed PDR ID and not both PDRs (primary and secondary).

Configuring the HR Roaming Support for UPF

This section describes how to configure the HR roaming support feature for UPF.

Configure Buffering Support of Visitors Calls on vUPF

To configure the buffering support of visitors calls on the vUPF, use the following CLI commands:

```
config
   user-plane [converged mode | buffered-packet-count [ instance-limit
instance_limit_value { session-limit session_limit_value} | { session-limit
session_limit_value { instance-limit instance_limit_value} ] ]
   exit
```

NOTES:

- **buffering-packet-count**: Configure max session and instance limit for buffering the packets.
- **instance-limit** *instance_limit_value*: Configures maximum number of packets to buffer for all session per SessMgr instance. The default range is 1 to 10000.
- **session-limit** *session_limit_value*: Configures maximum number of packets to buffer per session. The default range is 1 to 255.

Verify the Buffering Support of Visitors Calls on vUPF

To verify the support of buffering limit for traffic on visitor calls on the vUPF, use the **show configuration** CLI command.

The following code is a sample output of the CLI command.

```
[local]qvpc-si# show configuration
...
...
    #exit
  user-plane buffered-packet-count session-limit 5 instance-limit 10
  context ingress
…
…
```

Configure the GTP-U Service and N9 Interface Association

To configure the association of GTP-U Service and N9 Interface, use the following CLI commands:

```
config
   context ingress
     user-plane-service user-plane-service
           associate gtpu-service service_name [ cp-tunnel | pgw-ingress |
 sgw-egress | sgw-ingress | upf-egress | upf-ingress | interface-type [
n9 | s5u | s8u | n3 | n9-s5u-s8u ] ]
           no associate gtpu-service upf-egress
     exit
```

```
   exit
exit
```

NOTES:

- **upf-egress**: Configure the interface type as UPF egress used for N9 interface.
- **interface-type [n9 | s5u | s8u | n3 | n9-s5u-s8u]**: Configure the desired GTP-U ingress interface type.

  Use the **n9-s5u-s8u** interface type a when single public IP address is used for N9, S5u and S8u interface types.
- **no associate gtpu-service upf-egress**: Configure to remove the GTP-U service and N9 interface association.

Verify the GTP-U Service and N9 Interface Association

To verify the association of GTP-U Service and N9 Interface, use the **show user-plane-service all** CLI command.

The following code is a sample output of the CLI command.

```
[local]qvpc-si# show user-plane-service all

Service name                        : user-plane-service
  Service-Id                        : 6
  Context                           : ingress
  Status                            : STARTED
  UPF Ingress GTPU Service          : sx-gtpu-service
  UPF Egress GTPU Service           : sx-upf_egress_gtpu
  SGW Ingress GTPU Service          : sx-sgw_ingress_gtpu
  SGW Egress GTPU Service           : sx-sgw_egress_gtpu
….
[local]qvpc-si# show configuration context ingress
config
  context ingress
....
...
   user-plane-service user-plane-service
      associate gtpu-service sx-gtpu-service upf-ingress
      associate gtpu-service sx-upf_egress_gtpu upf-egress
      associate gtpu-service sx-sgw_ingress_gtpu sgw-ingress
      associate gtpu-service sx-sgw_egress_gtpu sgw-egress
      associate gtpu-service up-gtpu cp-tunnel
      associate sx-service sxu
      associate control-plane-group g1
    exit
...
```

Roaming Status in Sub-Params IE

The following is an example of the Sub-Params IE that displays the roaming status:

```
SUBSCRIBER PARAMS:
Type: 226
Rat-Type: 3
SGSN-Address: 20.20.20.17
ULI: ECGI=216354001234c800
GGSN-Address: 20.20.20.3
Roaming-Status: Homer/Roamer/Visitor-hr/Visitor-LBO
```

Source Interface Type IE

The Source Interface Type IE indicates the 3GPP interface type of the source interface.

The 3GPP Interface Type IE indicates the 3GPP interface type of the source interface within the PDR IE, or the 3GPP interface type of the Destination Interface within the FAR IE.

The following is an example of Create PDR that displays Source Interface Type:

```
CREATE PDR:
    Type: 1
    Value:
PDR ID:
    Type: 56
    Value:
        RULE ID: 0x0002
PRECEDENCE:
    Type: 29
    Value: 0x00000001

PDI:
Type: 2
Value:
SOURCE INTERFACE:
    Type: 20
    Value: CORE (1)
Traffic Endpoint ID:
    Type: 131
    Value: 0x0001
SOURCE INTERFACE TYPE:
    Type: 160
    Value: N9 (0x0F)
FAR ID:
    Type: 108
    Value: 0x8002
RULEBASE:
    Type: 207
    Value:
QER ID:
    Type: 109
    Value: 0x80000001
```

Monitoring and Troubleshooting

This section provides troubleshooting information for this feature.

show user-plane-service statistics all

To monitor the statistics for the user plane service, use the following CLI command:

show user-plane-service statistics all

The following is a sample output:

```
[local]qvpc-si# show user-plane-service statistics all

…
PDNs By PLMN-Type:
 Homer Subscriber PDNs:
    Active:                          0    Setup:                              0
```

```
    Released:                       0
 Roamer Subscriber PDNs:
    Active:                            0    Setup:                              0
    Released:                       0
  Visited-Home-Routed Subscriber PDNs:
    Active:                            0    Setup:                              0
    Released:                       0
  Visited-Local-Breakout Subscriber PDNs:
    Active:                            0    Setup:                              0
    Released:                       0
…
Inter-PLMN Handover Statistics:
   Attempted  : 0                    Succeeded  : 0
   Failed.        : 0

  Intra-PLMN Handover Statistics:
   Attempted   : 0                   Succeeded  : 0
    Failed.        : 0
…
  PDNs Rejected By Reason:
…
…
  Data Statistics Related To Paging:
    Packets Buffered:                  5    Bytes Buffered:                   420
    Packets Discarded:                 1    Bytes Discarded:                   84

  Total Data Statistics:
```

show subscribers user-plane-only full all

To see all the subscribers using the user plane service, use the following CLI command:

show subscribers user-plane-only full all

The following is a sample output:

```
….
Converged Session: No                 Converged Peer Callid:      n/a
Visited Call: Yes
Subscriber Parameters:
…..
Interface Type: N4
….
Subscriber Parameters:
IMSI: 123456789012345
….
Old Rat Type: 6
…
Session-ID: 1414146500000001
Roaming Status: Homer
Old Roaming Status: Homer
…
```

show subscribers user-plane-only callid pdr full all

The **show subscribers user-plane-only callid** *call_id* **pdr full all** command displays all PDR information.

The Source Interface Type field displays the Source Interface Type IE received from SMF.

The following is a sample output of this command:

show subscribers user-plane-only callid *call_id* **pdr full all**

```
show subscribers user-plane-only callid 0098e4b0 pdr full all
Callid: 0098e4b0
Interface Type: N4
…
Matched Bytes:            0
Matched Packets:          0
Precedence:               0
Source Interface:         Access
Source Interface Type:    N9
Local F-TEID:    0x16001
Local F-TEID IP Addr:
  IPv4:          20.20.20.15
  IPv6:          N/A
…
Bearer Level Info-id:   N/A
Secondary Pdr Info:
   Pdr ID :   2 / NA
   Local F-TEID:    0x1a001
   Local F-TEID IP Addr:
         IPv4:          20.20.20.15
         IPv6:          N/A
   QoS Flow Identifier: 1 / NA
   Source Interface Type:  S5U
```

show user-plane-service gtpu statistics gtpu-service n9-egress

The following is a sample output of this command for visiting UPF:

```
[local]Test-UPF4# show user-plane-service gtpu statistics gtpu-service n9-egress

Total Data Stats:
Uplink Packets: 10 Uplink Bytes: 2400
Downlink Packets: 10 Downlink Bytes: 2400
Packets Discarded: 0 Bytes Discarded: 0

QoS Stats:

QCI 1:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 2:
Uplink Packets: 8 Uplink Bytes: 1920
Downlink Packets: 8 Downlink Bytes: 1920
Packets Discarded: 0 Bytes Discarded: 0

QCI 3:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 4:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 5:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 6:
```

```
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 7:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 8:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 9:
Uplink Packets: 2 Uplink Bytes: 480
Downlink Packets: 2 Downlink Bytes: 480
Packets Discarded: 0 Bytes Discarded: 0

QCI 65:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 66:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 69:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 70:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 80:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 82:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 83:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

Non-Std QCI(Non-GBR):
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

Total uplink packets GBR QCI's: 8
Total uplink Bytes GBR QCI's: 1920
```

```
Total Downlink packets GBR QCI's: 8
Total Downlink Bytes GBR QCI's: 1920
Total uplink packets Non-GBR QCI's: 2
Total uplink Bytes Non-GBR QCI's: 480
Total Downlink packets Non-GBR QCI's: 2
Total Downlink Bytes Non-GBR QCI's: 480

Path Management Messages:
Echo Request Rx: 29 Echo Response Rx: 10
Echo Request Tx: 10 Echo Response Tx: 29
SuppExtnHdr Tx: 0 SuppExtnHdr Rx: 0

Peer Stats:
Total GTPU Peers: 1
Total GTPU Peers with Stats: 1

Tunnel Management Messages:
Error Indication Tx: 0
Error Indication Rx: 0
Error Indication Rx Discarded: 0
```

show user-plane-service gtpu statistics gtpu-service n9-ingress

The following is a sample output of this command for roaming UPF:

```
[local]Test-UPF3# show user-plane-service gtpu statistics gtpu-service n9-ingress

Total Data Stats:
Uplink Packets: 25 Uplink Bytes: 6000
Downlink Packets: 24 Downlink Bytes: 5760
Packets Discarded: 0 Bytes Discarded: 0

QoS Stats:

QCI 1:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 2:
Uplink Packets: 19 Uplink Bytes: 4560
Downlink Packets: 18 Downlink Bytes: 4320
Packets Discarded: 0 Bytes Discarded: 0

QCI 3:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 4:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 5:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 6:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0
```

```
QCI 7:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 8:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 9:
Uplink Packets: 6 Uplink Bytes: 1440
Downlink Packets: 6 Downlink Bytes: 1440
Packets Discarded: 0 Bytes Discarded: 0

QCI 65:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 66:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 69:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 70:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 80:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 82:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

QCI 83:
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

Non-Std QCI(Non-GBR):
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0
Uplink Packets: 0 Uplink Bytes: 0
Downlink Packets: 0 Downlink Bytes: 0
Packets Discarded: 0 Bytes Discarded: 0

Total uplink packets GBR QCI's: 19
Total uplink Bytes GBR QCI's: 4560
Total Downlink packets GBR QCI's: 18
Total Downlink Bytes GBR QCI's: 4320
Total uplink packets Non-GBR QCI's: 6
```

```
Total uplink Bytes Non-GBR QCI's: 1440
Total Downlink packets Non-GBR QCI's: 6
Total Downlink Bytes Non-GBR QCI's: 1440

Path Management Messages:
Echo Request Rx: 10 Echo Response Rx: 31
Echo Request Tx: 31 Echo Response Tx: 10
SuppExtnHdr Tx: 0 SuppExtnHdr Rx: 0

Peer Stats:
Total GTPU Peers: 1
Total GTPU Peers with Stats: 1

Tunnel Management Messages:
Error Indication Tx: 0
Error Indication Rx: 0
Error Indication Rx Discarded: 0
```